A PHOTOGRAPHIC CAMERA TO THE 600/7500 mm TELESCOPE. CONSTRUCTION AND INVESTIGATION.

R. M. Roussev, G. T. Petrov, T. S. Rousseva

1. INTRODUCTION

"Rozhen" National Astronomical Observatory and its branch office in the town of Belogradchik include in their observational basis 600/7500 mm mirror telescopes Cassegrain system (the diameter of the main mirror - 600 mm, equivalent focal distance - 7500 mm, A = 1:12,5, M = 27,5 "/mm) made by the people's enterprise "Carl Zeiss Jena", GDR[+]. The telescopes are equiped only with object finders (F = 750 mm, A = 1:6,8, $\alpha = 8^{\circ}\!,4$) and they do not have guiding tubes. The enterprise does not offer light-receiving appliances for this type of telescopes. That is why, in order to solve a certain concrete observational task one have to construct and work out in addition such an appliance.

Due to their, relatively small observational field, the 600/7500 mm telescopes are suitable for photoelectric observations. This fact, however, does not exclude the possibility for their use for other purposes. As our experience throughout the last ten years shows it, they could be used successfully for photographic observations too in the cases when the observed objects occupy small parts of the sky. In order to study the globular star clusters in the Galaxy (searching and examination of variable stars of different types, multicolour photographic photometry, the study of the structure of these aggregates, etc.) we

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[+] In the nearest future such a telescope would be installed in the People's Astronomical Observatory "Peter Beron" near the town of Sliven ("Karandilla"), Bulgaria.

constructed, built up and examined a photographic camera with guiding eyepiece, designed for the 600/7500 mm telescopes, being itself a part of a combined complex receiving appliances. Up to now about 300 photographs in B, V and R of 9 globular clusters have been obtained (M 2, 3, 10, 12, 13, 15, 56, 71 and 92), as well as those of several open clusters (Pleiades, Praesepe, M 39, 44, 67, NGC 6709, 6819, 6910 and IC 4665). The results of the examination of a part of the obtained photographs were published elsewhere (Russev, Russeva, 1979a, 1979b, 1979c; Russeva, Russev, 1980, 1983; Russeva, Iliev, Russev, 1982; Russev, Peikov, 1986).

2. CONSTRUCTION OF THE CAMERA

The main parameters of the appliance are defined by place for fixing of the ocular part to the telescope behind the Cassegrain aperture, the diameter of that aperture (80 mm), and by the disposition of the focal plane behind the aperture when the secondary mirror is in medial position. Fig. 1a and 1b presents a schematic assembly drawing of the camera and its general appearance in operating conditions as mounted to the telescope in the town of Belogradchik. The camera includes the following three separate parts:

Bearing positional disc (1 in Fig. 1a). Due to its function the whole construction could rotate around the main optical axis of the telescope. The rotation is accomplished by toothed gearing. The latter is calculated in such a way that in a case of total loading up to 30 kg the effort necessary for the rotation of the system would be smaller than 1 kg. At intervals of 1 arc min divisions are marked on the face part of the disc. Three stopping screws fix steadily the chsen position. The bearing disc could be used separately for fixing of any other lighttaking appliances to the telescope.

Ocular part (2 in Fig. 1a). It contains a guiding eyepiese (3 in Fig. 1a), manual shutter and a place for putting different kinds of lightfilters. Using two prisms with full internal reflection, a part of the field is transferred toward the guiding eyepiece, which contains illuminated filar cross. The eyepiece system could be moved radially, from the centre to the end of the observed field. This movement taken together in cmbination with the rotation of the bearing disc allows complete observation of the objects which are to be photographed and a choice of suitable for guiding star. Built up like a separate assembly, the ocular part is intended to be used as a part of electrophotometer too, as well as in the cases of photographing by the aid of image tubes.

Casette part (4 in Fig. 1a). It includes a casette-holder and a photoplate-casette with dimensions 6x9 and 9x12 cm. The standart lightfilters used have diameters 49 mm and they limit the photographed stellar field up to that diameter, which coresponds to 22,5 arc min.

Constructive drawings of the camera are given in details in the work of Petrov (1974).

3. PUTTING INTO PRACTICE THE B, V AND R PHOTOMETRIC SYSTEMS

The use different photoemulsions and suitably chosen lightfilters enables one to obtain photographs in different parts of the spectrum using the camera. Having in mind our tasks and our possibilities for supply of photoemulsions, the photographs obtained up to now are in the broad-band photometric systems B, V and R. In Table 1 are given the used photoemulsions, lightfilters and the equivalent wavelengths of the respective curves of reactions (λ_e) and their semiwidths ($\Delta\lambda$). In order to obtain λ_e and $\Delta\lambda$ the mean curves of spectral sensitivity of the photoemulsions according the wedge-shaped spectrogrammes of "ORWO" were used, while the curves of the permeability of the filters were obtained by the aid of laboratory automatic spectrophotometer "Specord". The last two columns of the Table 1 give for comparison the standard values of λ_e and $\Delta\lambda$ for the bands B, V and R. The B-system is nearest to the standard. Most of our plates are taken in this system. We must note also that the filters were made by "Panchromar", FRG.

Table 1

System	Photo-emulsion	Filter		λ_e	$\Delta\lambda$	Standard λ_e	Standard $\Delta\lambda$
B	ZU 2(21)	UV II	(1,6 mm)	4650	1050	4415	960
V	ZP 3	GM	(1,6 mm)	5760	1700	5505	830
R	I 750	R	(1,7 mm)	7500	1000	6800	2300

Figure 2 represents a reproduction of the globular star cluster M 13 from a plate obtained by the camera in blue light (B system, plate No. 69, 13.08.1977, 30 min exposure time, stellar images $\sim 2''$). On the original plate one can see stars from up to 18 magnitude.

4. EXAMINATION OF THE CAMERA

4.1. DETERMINATION OF THE NONVIGNETTED FIELD DIAMETER

Using the geometric and optical characteristics of the telescope combined with the camera, the theoretical results are that the nonvignetted field in the plane of the plate has to be 38 mm ($17'.4$). The experimental check of this conclusion was carried out through photography of the trecks left by the bright stars of the open star cluster NGC 6918 when the telescope is stoped. The results of the photometry (using MF-2 photometer with square slit) of the obtained B plates are given in Figure 3a. The absciss gives the distances from the centre of the field in mm, while the ordinate gives the change in the illuminations throughout the diameter of the field in stellar magnitudes (ΔB). The real diameter of the nonvignetted field appeared to be equal to 36 mm ($16\overset{'}{,}5$), that is slightly smaller than the calculated theoretical results. The standard deviation of the dots across the diameter of the nonvignetted field is $\sigma = \pm 0\overset{m}{,}02$.

4.2. PHOTOMETRIC ERROR OF THE FIELD

The photometry of 10 standard stars of the open cluster NGC 6910 on a B plate with 15 min exposure time shows that in the interval of about four magnitudes (from $8\overset{m}{,}5$ to $12\overset{m}{,}5$ in Fig. 3b) the maximum deviation ΔB from the mean calibration curve do not exceed $\pm 0\overset{m}{,}06$. In approaching to the limit magnitude of the stars over the plate ($\sim 16^{m}$) the deviations grow and they reach up to $\pm 0\overset{m}{,}15$. The growth of ΔB when $B > 12\overset{m}{,}5$ is due to the limited possibilities of the square slit photometers and to the coming near to the not fully exposured part of the calibration curve.

The deviations $|\Delta B|$ and the (B-V) colours are cofronted in Figure 3c. It is seen that the deviations do not depend on the colour of the stars which is very natural in mind the system used: mirror telescope - filter - photoplate.

The measurements of the NGC 6910 stars on V and R plates show analogical results to those shown in Figures 3b and 3c.

4.3. DEPENDENCE OF THE LIMIT STELLAR MAGNITUDE ON THE DURATION OF THE EXPOSURE TIME

Using the processed up to now observational material we obtained the dependece between the B magnitude of the faintest stars about which we can make confident photometric measurements on the duration of the exposure time (Figure 4). It should be noticed also that on the plates one could see even stars which are fainter with $0^m_{,}5$ - $1^m_{,}0$ than the ones used for the obtaining of the dependence but their photometry is not very confident.

Using one and the same instrument and method for the obtaining of photographic observational material for a given exposure time, the limit magnitude depends very much on the atmospheric conditions. The dependence shown in Fig. 4 refers to the images of stars with 2-3" while the position of the dots was obtained as a mean value of several photoplates with standard error $\sigma(B) \approx \pm 0^m_{,}2$.

Using the seven dots in Fig. 4 we obtained the dependence:

$$B = \underset{\pm,1}{13{,}9} + \underset{\pm,04}{1{,}85}\ \lg t \qquad /1/$$

where the exposure time (t) is measured in minutes. The coefficient before $\lg t$ is equal to $2{,}5\,p$ where p is the photographic effect index in the law of Schwarzschild. Therefore the mean value of this index for the emulsions used in our observations ZU 2(21) is $p = 0{,}74 \pm 0{,}04$.

The experience shows that for the obtaining of the same limit magnitude in V and R systems the exposure time have to be increased respectively about 4 or 8 times in the cases of hypersensibilized with distilled water emulsions ZP 3 and I 750.

4.4. DEPENDENCE OF THE FOCUS ON THE TEMPERATURE DURING THE TIME OF OBSERVATIONS

The result from the obligatory focusing of the camera using the generally known methodics prior to each cycle of observations is the dependence in Figure 5 between Φ (the position of the secondary telescope mirror in mm) and the temperature during the time of observation ($t^{o}C$) for the telescope in the town of Belogradchik. From the respective formula

$$/2/ \qquad \Phi = \underset{\pm,033}{10,566} + \underset{\pm,0025}{0,0106}\,t$$

expressing the linear expansion of the frame construction which carries the main and the secondary mirror of the telescope according to the neighbouring temperature we obtain directly that the coefficient of the linear expansion of the construction is $\alpha \approx 3.10^{-6}\ K^{-1}$. In addition, it turned out that formula 2 is valid for each of systems B, V and R.

The details in connection of the examination and utilization of the camera could be found in the work of Russeva (1982).

Recently using the working drawings of the camera (Petrov, 1974) and by the aid of our consultation, the collaborators of the People's Astronomical Observatory "Nicolaus Copernicus" in the town of Varna built up analogical photographic camera designed for the 500 mm mirror telescope Cassegrain system in the village Avren. Now the device is in the period of experimental exploitation and examination.

In conclusion, the authors of the present examination take the opportunity to express their gratitude to the craftsmen at the Mechanical Workshop in the Physics Faculty at the Sofia University for the manufacture of the mechanical parts of the camera.

Fig.1a

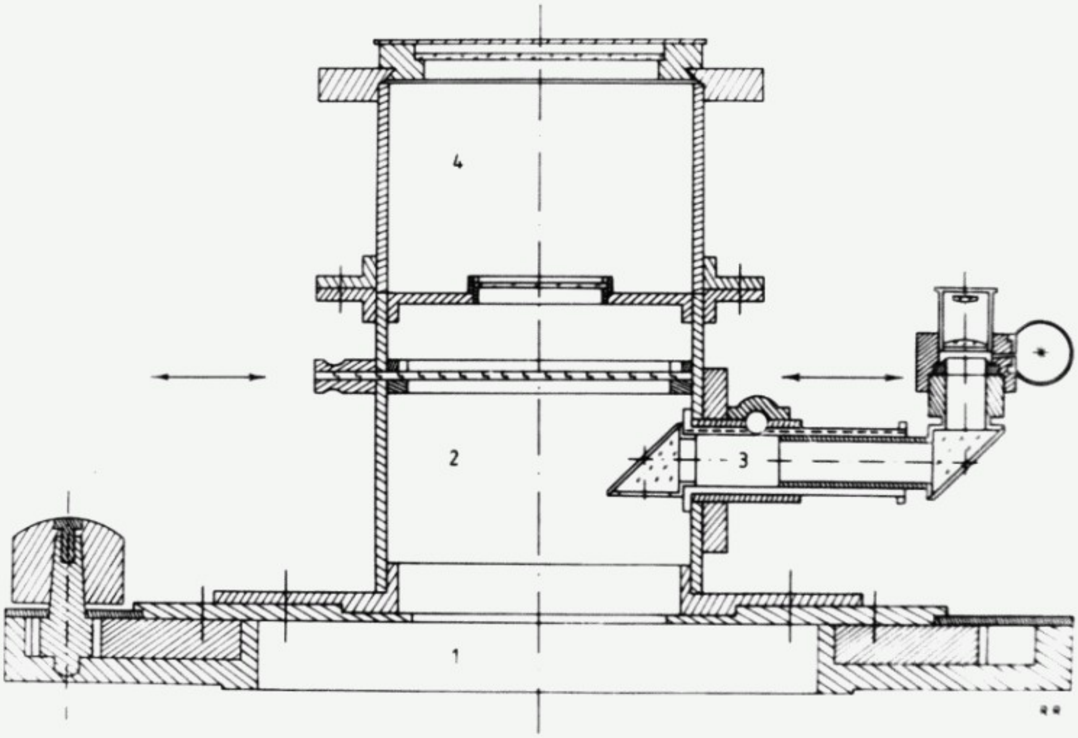

Fig.1b

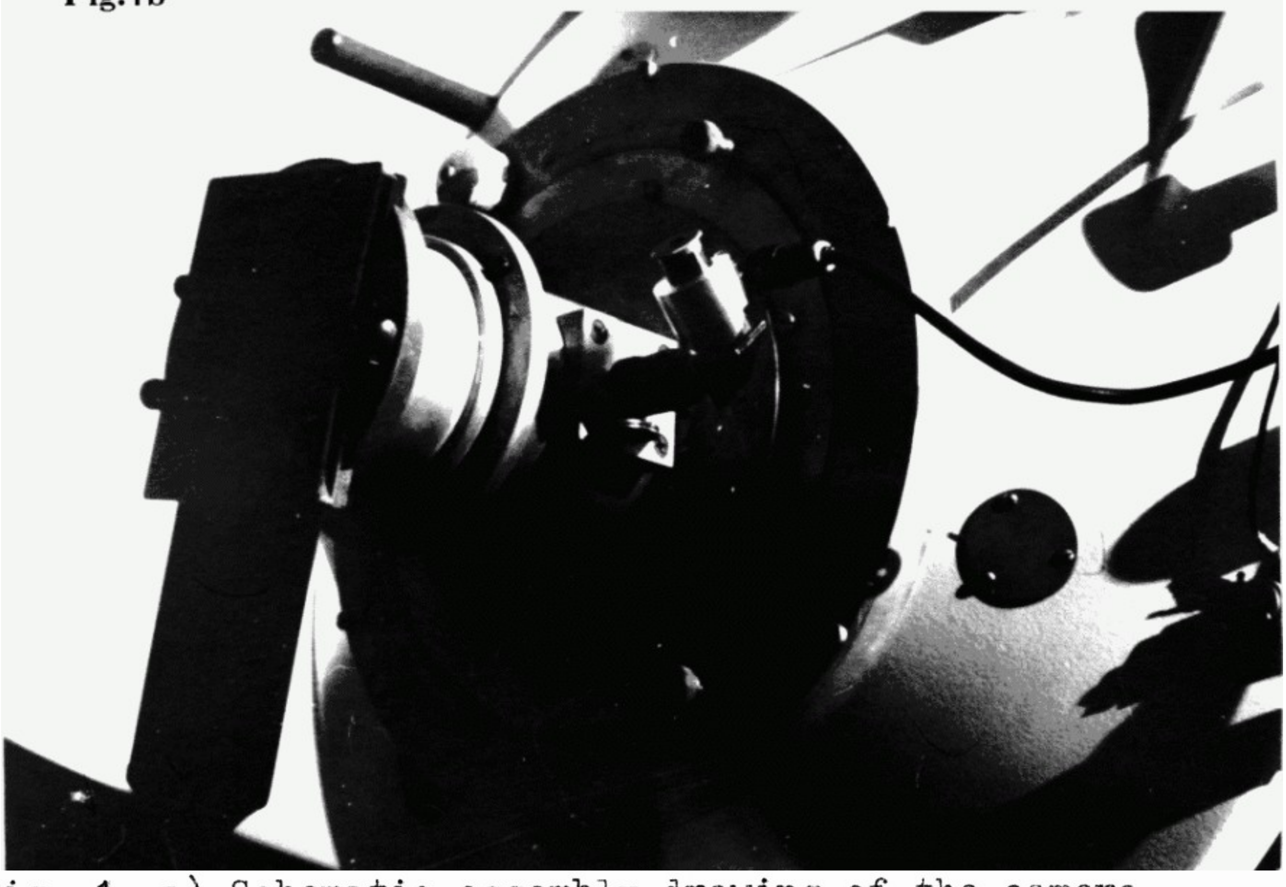

Fig. 1. a) Schematic assembly drawing of the camera.

b) General appearance of the camera in operating conditions as mounted to the telescope in the town of Belogradchik.

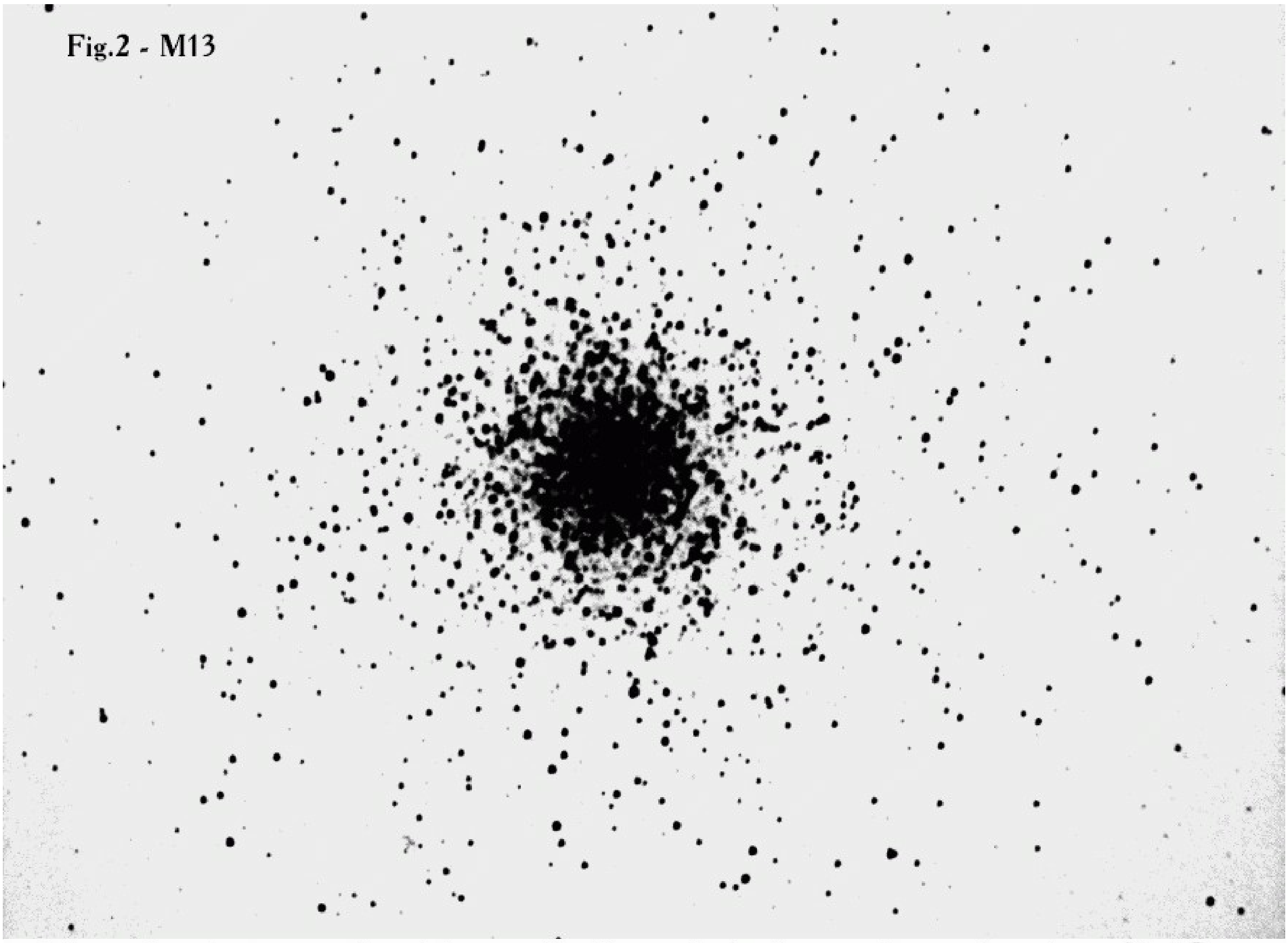

Fig. 2. A reproduction of the globular star cluster M 13 in blue light (B plate No. 69, 13.08.1977, 30 min exposition).

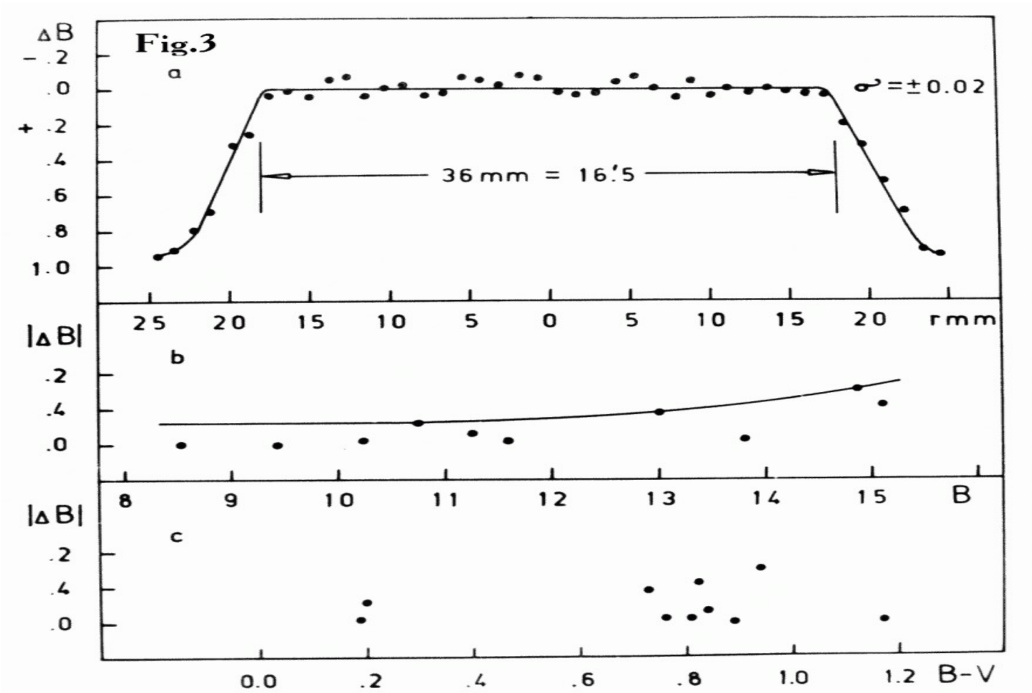

Fig. 3. a) A nonvignetted field of the camera.

b) Dependence of the photometric error $|\Delta B|$ on the B magnitude.

c) The photometric error $|\Delta B|$ against the (B-V) colour.

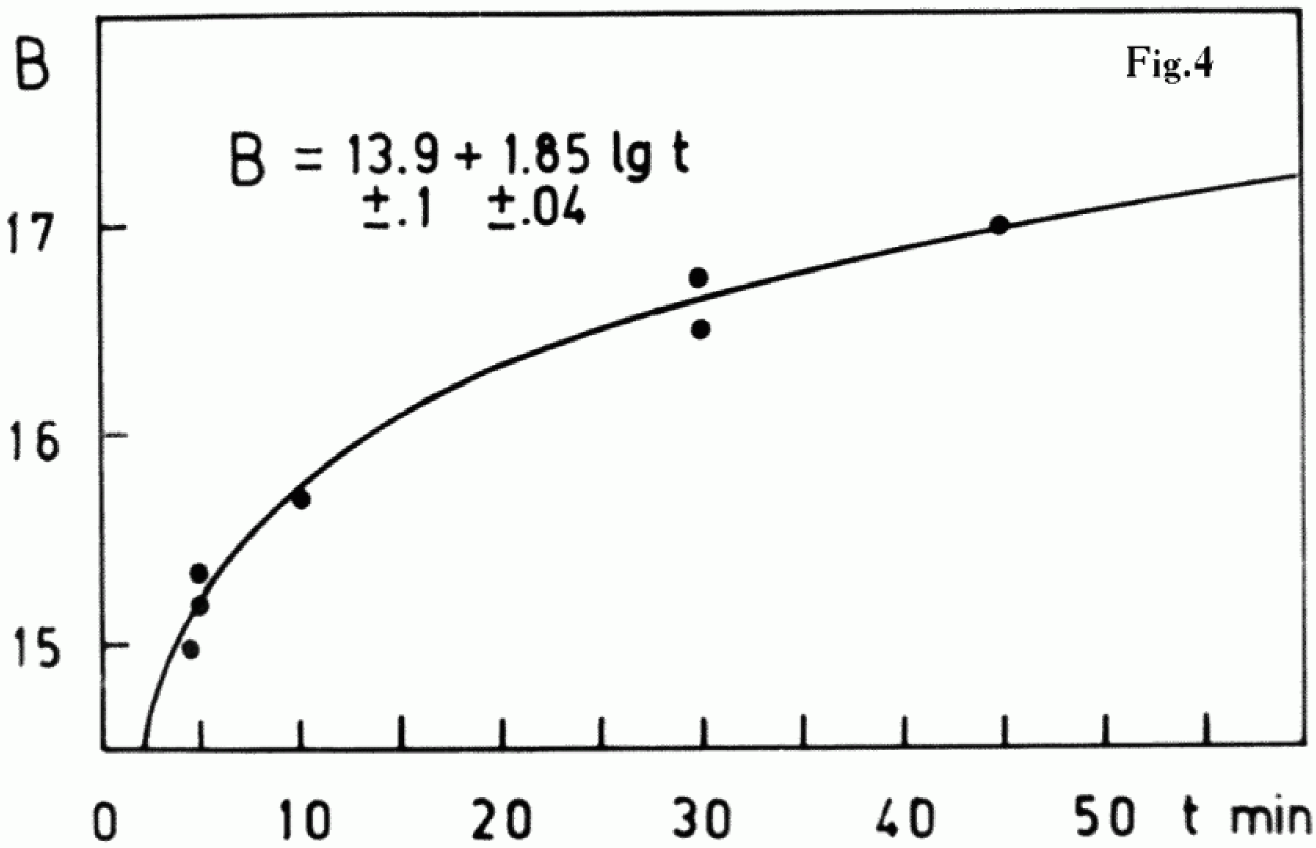

Fig. 4. Dependence between the B magnitude of the faintest star which confident photometric measurements could be made and the duration of the exposition.

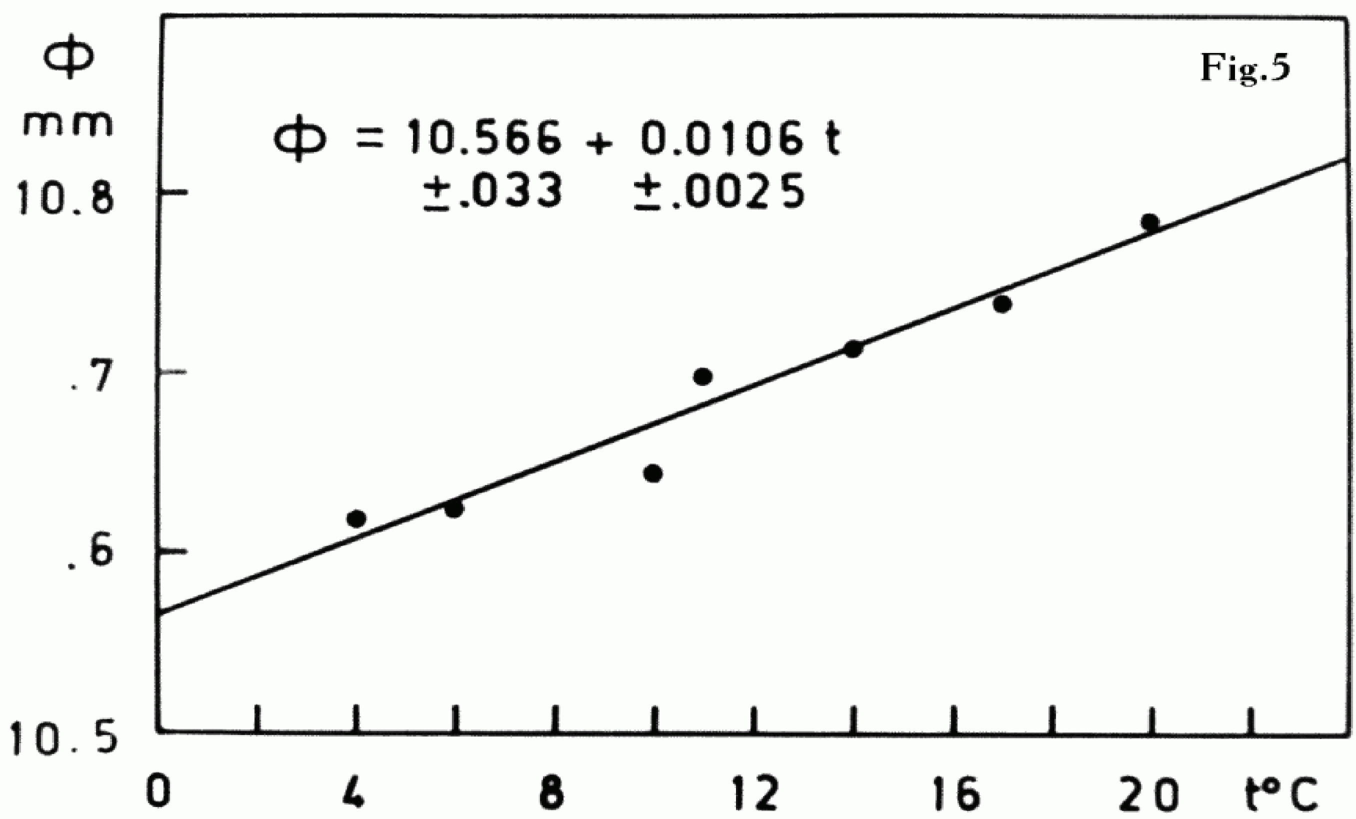

Fig. 5. Dependence of the focus Φ (the position of the secondary mirror) on the temperature in the town of Belogradchik.

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Аннотация

Фотографическая камера к 600/7500 мм телескопу.
Конструкция и исследование.

Р. М. Русев, Г. Т. Петров, Т. С. Русева

Рассматривается конструкция и результаты исследования фотографической камеры с гидирующим окуляром для 600/7500 мм кассегреновских телескопов фирмы "Карл Цейсс Йена", ГДР. Такие телескопы установленны на Национальной астрономической обсерватории "Рожен" и ее филиал в г. Белоградчике, БНР. На этих телескопах при помощи камеры за последные 10 лет получены около 300 пластинок нескольких шаровых и рассеянных скоплений нашей Галактики.

Сборной чертеж камеры показан на рис. 1а, где 1 - позиционирующое посадочное кольцо, 2 - окулярная часть, 3 - гидирующий окуляр, 4 - кассеточная часть. Вид камеры, установленной на телескопе г. Белоградчика, показан на рис. 1в. Эмульсии и фильтры, использованные для осуществления широкополосных фотометрических систем B, V и R, а также эквивалентные длины волн кривых реакции /λ_e/ и их полуширины /$\Delta\lambda$/, приведены в табл. 1. На рис. 2 дана репродукция звездного скопления М 13 из пластинки полученной при помощи камеры.

Исследование камеры показало, что диаметр невиньетированного поля равняется 36 мм или $16'\!.5$ /рис. 3а/, а фотометрическая ошибка поля не превышает $\pm 0^m\!.06$ в системе B на протяжения 4^m, пользуясь для фотометрирования фотометром МФ-2 с квадратной диафрагмой /рис. 3в/. Кроме того, фотометрическая ошибка не зависит от цветов звезд /рис. 3с/. Зависимость предельной B величины звезд, фотометрируемые уверенно на пластинках, от продолжительности экспозиции в минутах /рис. 4/ выражается формулой /1/. Наклон зависимости "$B_{пр} - \lg t$" дает, что показатель в законе Шварцшильда для эмульсий ZU 2 и 21 в среднем равнается $0{,}74 \pm 0{,}04$. Зависимость фокуса Ф /положения вторичного зеркала/ от температуры во время наблюдений /$t\ ^oC$/ для телескопа г. Белоградчика показана на рис. 5 и выражается формулой /2/. Из зависимости следует, что коэффициент линейного расширения рамочной конструкции телескопа около 3.10^{-6} K^{-1}.

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